**Photosynthesis (SBI4U)**

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**Background Information**

All living things need energy for their chemical reactions which aid in the growth, reproduction, and sustainability of that organism. Photosynthetic organisms utilize sunlight as its energy source to produce sugar (i.e. carbohydrate). This stored sugar, can be used for energy at a later time. This process is outlined by the following equation:

6CO2 + 6H2O + Energy  C6H12O6 + 6O2

Photosynthesis can occur through light dependent (i.e. Calvin cycle) or light independent reaction. The lesson sequence below outlines the various topic to be covered when teaching photosynthesis.

**Curriculum Expectations**

**Overall Expectations**

* C2. investigate the products of metabolic processes such as cellular respiration and photosynthesis
* C3. demonstrate an understanding of the chemical changes and energy conversions that occur in metabolic processes

**Specific Expectations**

* C2.3 conduct a laboratory investigation of the process of photosynthesis to identify the products of the process, interpret the qualitative observations, and display them in an appropriate format
* C3.2 explain the chemical changes and energy conversions associated with the process of photosynthesis (e.g., carbon dioxide and water react with sunlight to produce oxygen and glucose)
* C3.3 use the laws of thermodynamics to explain energy transfer in the cell during the processes of cellular respiration and photosynthesis
* C3.4 describe, compare, and illustrate (e.g., using flow charts) the matter and energy transformations that occur during the processes of cellular respiration (aerobic and anaerobic) and photosynthesis, including the roles of oxygen and organelles such as mitochondria and chloroplasts

**Advance Information**

*Biology*

Students should be aware that photosynthesis is an essential process by which plants, some bacteria and protistans utilize the sun to make sugar. This process is followed by cellular respiration which converts the sugar into ATP and this ATP molecule is used as "fuel" for all living things.

**6H2O + 6CO2 ----------> C6H12O6+ 6O2**

This reactions occur due to the green pigment in plants called chlorophyll. It uses six molecules of water and 6 molecules of carbon dioxide to produce one sugar molecule and 6 molecules of oxygen. Students *should* also have the knowledge that the reverse of this reaction is cellular respiration.

*Chemistry*

Students should have a solid understanding of: atoms, molecules, forward and reverse reactions, equilibrium, balanced equations, and electron flow to fully understand this topic.

**Special Materials**

* column chromatography kit OR
* chromatography paper

**Student Difficulties**

|  |  |
| --- | --- |
| **Misconceptions** | **Suggestions** |
| Students are confused with the terminology of: food, starch, sugar, glucose | Use these words interchangeably during the lessons so that students become comfortable with them |
| Photosynthesis occurs only in green plants | All plants have chloroplasts and therefore all plants undergo photosynthesis |
| Plants obtain energy directly from the sun | Photons are absorbed by photosystems  and excited electrons through  photon excitation and they enter the  electron transport chain |
| Plants do not respire or they only respire at night | Explain that photosynthesis has light  *independent reactions* and can respire at  night |
| The world’s supply of oxygen is in danger of being used up | Oxygen is limitless. High amounts of CO2  emissions is what is causing climate change |

**Teaching Ideas**

Several pedagogies can be employed to effectively teach photosynthesis. This topic requires students to remember a lot of detail and as such teachers can use a lot of graphic organizers and diagrams (flow charts, Venn diagrams, videos, PowerPoint, etc). These visuals, along with written notes will help students to who are either or both visual and auditory learners.

Teachers can also utilize hand-on activities (i.e experiments, dry labs, jigsaw, etc) to helps those students who kinesthetic learners. These students learn best through a variety of teaching styles, by moving around during an activity and role-play. If possible, teachers should try to provide more small group discussions (Think-Pair-Share) within the unit.

**Overall Lesson Sequence**

Lesson 1: Photosynthetic Organisms

Lesson 2: Light Energy and Photosynthetic Pigments

Lesson 3: Photosynthesis: The Light Reactions

Lesson 4: Photosynthesis: The Dark Reactions

Lesson 5: Photosynthesis and the Environment

Lesson 6:Photosynthesis vs. Cellular Respiration: Jeopardy Game

**Detailed Lesson Sequence**

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| --- | --- | --- | --- |
| **Topic** | **Lesson Outline** | **Resources** | **Assessment/Evaluation** |
| Photosynthetic Organisms | * Chlorophyll * Prokaryotic Autotrophs: Cyanobacteria * Eukaryotic Autotrophs: Algae, Photosynthetic * Protists and Plants * Leaves: The Photosynthetic Organs of Plants * Transpiration and Photosynthesis * Opening and Closing of Stomata * Chloroplasts | Computer Lab Activity Gizmo - Energy Cell Cycle; Growing Plants | Venn Diagram: Eukaryotic vs. Prokaryotic Plants  Question and Answers during the lesson |
| Light Energy and Photosynthetic Pigments | * \*\*Note see chart below | Chlorophyll Extraction  http://www.youtube.com/watch?  v=keMssMr3aqw&feature=related | reflection question on dry lab activity |
| Photosynthesis: The Light Reactions | * Capturing Light Energy   • Photosystems (P680 and P700)   * antenna complex * reaction centre * Using captured light energy to make ATP and reduced NADP\* | The Light Reactions: http://www.youtube.com/watch?v=hj\_WKgnL6MI  Virtual Lab *- Plant Pigment and Photosynthesis (Lab 1 - Chromatography; Lab 2 -*  *Photosynthesis)*  http://www.phschool.com/science/biology\_place/labbench/lab4/intro.html | Think-Pair-Share: What happens to photosynthesis when the sun is no longer out?  Assessment and/or evaluation on the virtual lab |
| Photosynthesis: The Dark Reactions | * Using the free energy of ATP and the reducing power of NADPH to synthesize organiccompounds, such as glucose, from CO2 * **The Calvin Cycle**   + Carbon Fixation   + Reduction Reactions   + RuBP Regeneration * **Alternative Mechanisms of Carbon Fixation**   + C4 Plants   + CAM   Cooperative Activity: Create a flowchart on the process of photosynthesis | Activity: *Factors Affecting the Rate of*  *Photosynthesis*  http://www.neiljohan.com/projects/biology/rateof-  photosynthesis.htm | Questions and Answers during the lesson  Diagnostic - how well students work cooperatively together |
| Photosynthesis and the Environment | * Net CO2 uptake * Net O2 evolution * Factors that affect the rate of photosynthesis in a plant   + Light Intensity   + Temperature   + Oxygen Concentration   + Photosynthetic Efficiency | Virtual Lab: Plant Pigment and Photosynthesis (Lab 1 - Chromatography; Lab 2 - photosynthesis)  http://www.phschool.com/science/biology\_place/  labbench/lab4/intro.html | Summative Task: Mini Quiz: Photosynthesis - Light and Dark Reactions (L3 and L4) |
| Photosynthesis vs. Cellular Respiration: Jeopardy Game | * Comparison of the Overall Reactions (Respiration and * Photosynthesis * Electrons * Electron Transport System * ATP Synthesis * Organelle Structure and Function * Mitochondrion vs. Chloroplast | Optional Activity: Investigating Photosynthesis and Respiration  through Kinesthetics and Inquiry  http://www.the-aps.org/education/k12curric/activities/pdfs/  carswell.pdf | Formative Assessment (Jeopardy Game): Teacher can use a game as feedback from students who understand the similarities and  differences between the two reactions |

**Evaluations Procedures**

Students are assessment almost everyday. This could be through the following (See Lesson Plan Overviews):

* Question and answer during the lesson (diagnostic/formative assessment)
* Short tests/quizzes - peer assessed or could be evaluated (summative assessment)
* Homework exercises - could collect one question for understanding (formative/summative)
* Mini activities – crosswords (formative/summative assessment)
* Diagrams – Venn diagram, flow chart, etc. (formative/summative assessment)
* Cooperative learning – Think-Pair-Share (formative assessment)
* Games – Jeopardy (formative assessment)

**Applications and Societal Issues/Implications**

Climate change effects photosynthesis

* Increasing levels of CO2 increases the photosynthetic pathways, especially for C3 plants that are subjected to high temperatures and minimal water supply
* Increasing levels of CO2 also affects plant growth

Invasive Plants - Kudzu and Purple Loosestrife

* **Kudzu** - this North American northward moving invasive vine reduces biodiversity by rapidly overtopping and killing vegetation by shading http://www.youtube.com/watch?v=tiYrqucl2vg
  + Hypothesis: at suboptimal temperatures, the depressed photosynthetic rate negatively impacts growth
* **Purple Loosestrife** – this perennial herb is a hardy plant that is also an aggressive invader

**References**

http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookPS.html

An awesome website for background information on photosynthesis

http://biology.clc.uc.edu/courses/bio104/photosyn.htm

A good website also on the background information on photosynthesis. This site also explains in detail what C3, C4 and CAM plants.

http://www.ncbi.nlm.nih.gov/pubmed/15143433

A great site for linking you to other resources.

http://abstracts.aspb.org/pb2009/public/P22/P22002.html

A link to the journal article on the applications of photosynthesis. More specifically, the kudzu, invasive vine in North America.

http://www.taosschools.org/ths/School%20Improvement/

CIEDipTTModule7TypesofFormativeAssessment.pdf

Good Ideas on assessment and evaluation.